Near Shore Wave Processes

Edward B. Thornton
Oceanography Department
Naval Postgraduate School
Monterey, CA 93943-5000
phone: (408) 656-284 fax: (408) 656-2712 email: thornton@oc.nps.navy.mil

Timothy P. Stanton
phone: (408) 656-3144 email: stanton@oc.nps.navy.mil

Award #'s: N0001499WR30116; N0001499WR30098; N0001499WR30146; N0001499WR30147
http://www.oc.nps.navy.mil/~thornton/
http://www.oc.nps.navy.mil/~stanton/

LONG-TERM GOALS

Long-term goals are to predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore given the offshore wave conditions.

OBJECTIVES

We hypothesize that the wave-induced kinematic, sediment and morphologic processes are nonlinearly interrelated at the same space and time scales, so that it is necessary to measure all processes simultaneous over the water column to understand individual processes. The primary mechanism for changes in moment flux that drives the near shore dynamics is due to the dissipation of breaking waves, the processes of which are poorly understood. To improve our understanding of breaking waves, the dissipation associated with bubble injection is measured along with the velocity fields over the vertical. Bottom boundary layer measurements are obtained to determine bottom stress and dissipation. Sediment transport is measured in response to the measured mean longshore and cross-shore currents, wave velocities and induced stresses. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment fields, is measured as a function of time and over large areas to examine cross-shore and alongshore variation.

APPROACH

Vertical distributions are measured throughout the water column of 3-component mean, wave-induced and turbulent velocities, bubbles, sediment concentrations from an instrumented sled. The 3-component velocity field is measured every 5 cm over the bottom 1 m with a downward looking 1.3 MHz bistatic coherent acoustic Doppler velocimeter, BCDV, (1.7 cm bin size at 48 Hz), and in the upper water column with a 300 KHz upward looking coherent bistatic acoustic Doppler velocimeter every 8 cm (8 cm bin size at 10 Hz). The BCDV also infers the vertical profile of suspended sediment concentration every 1.7 cm over the bottom 1m from the acoustic backscatter intensity. In addition, the vertical profiles of the horizontal velocities are measured with an array of 8 electromagnetic current meters. A 2 m cross-shore array of six optical backscatter instruments measures the horizontal

Report Documentation Page	*Form Approved OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1999		**00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Near Shore Wave Processes**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Department of Oceanography,Monterey,CA,93943**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

coherence length scale and advection. The small-scale morphology is measured with an array of 7 sonic altimeters mounted on the back of the CRAB, and from the sled with a x-y scanning altimeter. Bubble injection and depth of bubble penetration are measured with the two acoustic systems (1.3 MHz looking down and 300KHz looking up), and with a 3 m vertical array of 8 conductivity cells. An important component of the cross-shore sediment flux is due to the cross-shore mean flow (undertow), which is forced by wave set-up/down; the set-up is measured with a cross-shore array of 8 pressure sensors. Set-up is an integral measure of the turbulent Reynold's stresses and wave radiation stresses and acts as a check for the detailed velocity measurements. The local sled measurements are placed in synoptic perspective using the continuously recording cross-shore array of pressure sensors to measure wave transformation and set-up, along with the current/wave sensor array of Elgar and Guza.

The SandyDuck measurements described above are the basis of our process modeling and analysis work. In addition, the comprehensive Delft3D morphology model was acquired from the Dutch and is being assessed using NSTS and SandyDuck wave, velocity and bathymetry fields.

WORK COMPLETED

The wave, velocity, void fraction, and small-scale morphology acquired during the intensive SandyDuck nearshore experiment 15 September- 31 October 1997 are being analyzed. The bottom profile during this period consisted of a well-defined outer bar and a short inner bar, bar terrace or at times no bar. The waves during the intensive 6 week experiment were unusually mild, with only one major storm. The sled data during SandyDuck was acquired over a larger range of tidal elevations compared with the Duck94 data, which allows greater examination of a range of breaking conditions.

Analysis and data processing tasks have focused on three areas:

1.) Sediment suspension and net fluxes using the BCDV backscatter-based sediment concentration profiles and three component velocity profiles to estimate stress and strain associated with sediment suspension events.
2.) Defining the cross-shore length scales of sediment events, using the horizontal OBS array and BCDV sediment profiles.
3.) Void fraction profiles in a surface-following coordinate system using the conductivity cell and EM current arrays in the mid- and upper- water column and the BCDV backscatter and velocities in the lower 50cm. The overlapping, but complimentary, range of turbulence and void fraction covered by these sensors is being exploited to define the water column turbulence and the influence of breaking waves.
4.) Vertical profiles of mean longshore and cross-shore velocities.

The BCDV was redesigned in conjunction with funding from the SHOWEX program to increase the vertical resolution for future nearshore bottom boundary layer studies. This work required significant hardware and software development, including the use of DSP processors in the instrument head to perform much of the Doppler processing.

RESULTS

The vertical profiles of strong (> 0.5 m/s) mean longshore currents during Duck94 were well described with a logarithmic profile (Garcez-Faria et. al., 1998). During SandyDuck, however, a number of profiles are significantly more uniform compared with a logarithmic profile, particularly over the bar. It is hypothesized that the more uniform profiles are a result of enhanced vertical mixing induced by wave breaking. The degree of uniformity is found correlated with the depth of void fraction penetration, a measure of the strength of wave breaking (Wiersma et. al., 1998).

The vertical profiles of suspended sediments were measure acoustically, and the vertical coherence length scale was found to be an order of magnitude greater than the wave boundary layer. The cross-shore horizontal coherence length scale of the suspended sediments was determined using a two-meter lagged array of six optical sensors. The horizontal coherence length scale, defined as the e-folding scale of the exponentially decreasing horizontal coherence, was approximately 0.8 time the rms wave orbital excursion length for all cross-shore stations. Both the vertical and horizontal coherence length scales are longest for infragravity waves and decrease with increasing frequency (Huck et. al., 1999)

The cross-shore distributions of mean longshore currents observed during the DUCK94 experiment were compared with predictions of a quasi three-dimensional near shore circulation model (Faria, Thornton, Stanton, Lippmann, Guza, and Elgar, 1999). The model includes forcing due to breaking waves described using the roller concept (Lippmann and Thornton, 1999), alongshore wind stress, cross-shore advection of mean momentum of the alongshore current, and a full non linear bottom shear stress. Contributions from the alongshore wind stress are mostly evident offshore and over the inner trough of the sand bar due to the relative increase in the wind force to wave force ratio as wave forcing decreases over these regions. Improvements for modeling of mean longshore currents compared with using the simple Thornton and Guza (1986) formulation of balancing the radiation stress gradient with the bottom shear stress for comparison was found to be O[50} percent improvement by incorporating a roller stress contribution (Lippmann and Thornton, 1999), and O[10] percent improvement by including the momentum mixing by the advection of the longshore current momentum by the mean cross-shore currents.

The small-scale morphology data acquired using altimeters mounted on the moving CRAB found surprising cross- and alongshore variability. The alongshore variability is not explainable due to variable wave and current conditions.

IMPACT/APPLICATIONS

The results obtained in process modeling of breaking waves, momentum mixing due to the interaction of longshore and cross-shore vertical mean profiles, and bottom shear stress enhanced by the form drag of wave and current induced bedforms are being transitioned to comprehensive nearshore models, including the Delft3-D morhphology model and the Comprehensive Community Model for Physical Processes in the Nearshore (NOPP).

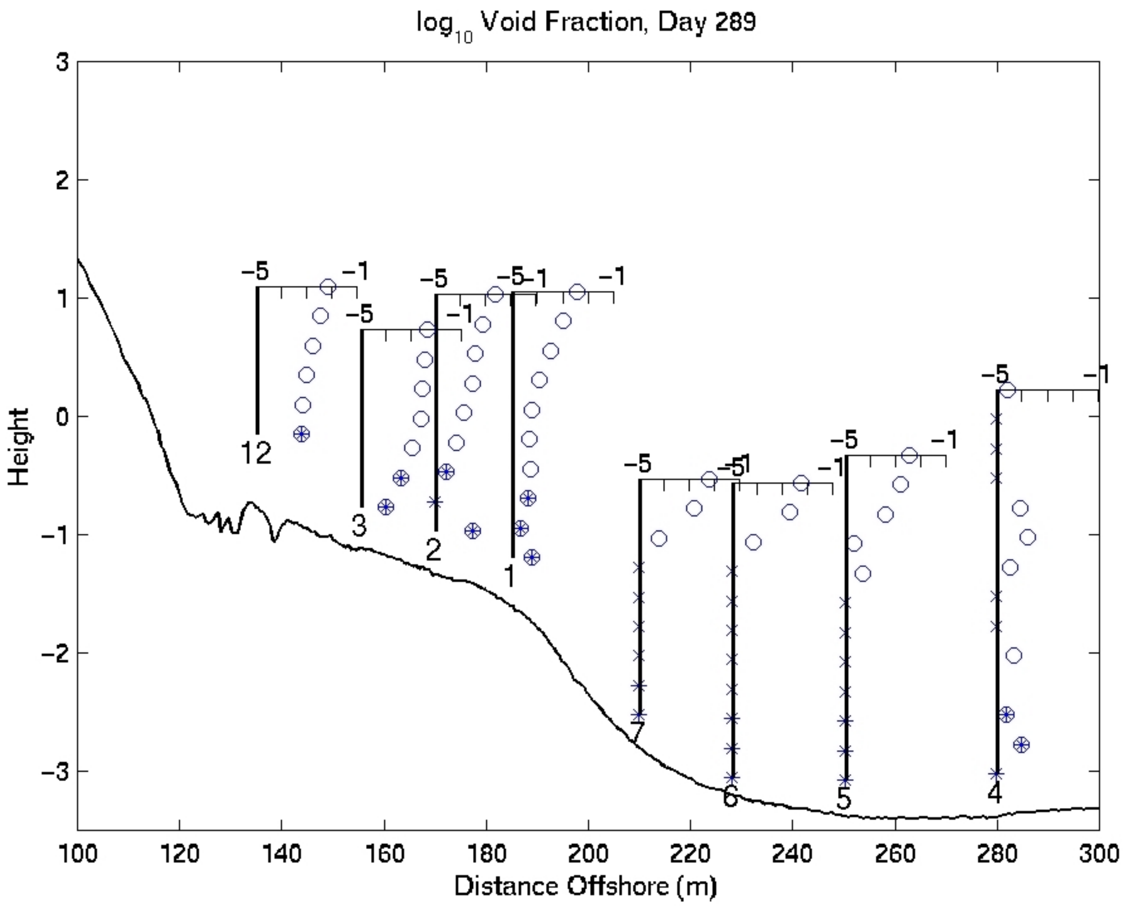

Figure (1) A cross-shore transect of bubble (void fraction) profiles measured on a day with offshore wave height of 1.6m, and 10 ms^{-1} wind speed. The one hour mean void fraction profiles are measured in a surface following reference frame, and each profile covers a 10^{-1} to 10^{-5} void fraction range. Weak (spilling) breaking waves offshore of the bar at stations 5,6 and 7 produce high near-surface air bubble fractions which rapidly attenuate with depth, in contrast with increasing depth penetration of bubbles with more intense wave breaking over the bar at stations 1 and 2. Sustained high void fractions are observed across most of the water column within the trough at stations 3 and 12.

TRANSITIONS

The Bistatic Coherent Doppler Velocimeter (BCDV) and x-y scanning altimeter developed under this project are being used in SHOWEX to measure wave dissipation due to bottom friction and small-scale morphology.

Work is under way to transition the process modeling results on undertow, longshore currents, and bedshear stress to modeling efforts funded under Surf Model (ONR), Modeling Wave Dissipation within the Wave Boundary Layer (ONR), and Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore (NOPP).

RELATED PROJECTS

1. Collaborative modeling of a turbulent wave boundary layer perturbed by an undulating bottom is being performed by Paulo Blondeaux, Giovanna Vittori and Piero Scudura from the University of Genoa through a NICOP program.

2. We participated in COAST3D with combined funding from NSF, ONR and NICOP.

3. Collaborative modeling and data comparisons of breaking waves using Boussinesq equations is being performed by PhD students at the U of Quebec under co-direction of Barbara Boczar-Karakiewicz and myself.

4. Analysis of SandyDuck data is being performed in collaboration with SandyDuck investigators Tom Lippmann, Bob Guza, Steve Elgar, Chuck Long and Bill Birkemeier.

5. Much of the instrumentation developed and procured under this program is being utilized in the Wave Shoaling DRI experiment, Sep-Dec 1999 also at Duck, NC.

6. Results of process modeling obtained on this project are being applied to nearshore modeling efforts under the following programs: Surf Model (ONR), Modeling Wave Dissipation within the Wave Boundary Layer (ONR), and Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore (NOPP).

PUBLICATIONS

Lippmann, T. C., T. H. C. Herbers, and E. B. Thornton, Gravity and shear wave contributions to nearshore infragravity, J. Physical Oceanography, 29 (2), 231-239.

Gallagher, E.L., S. Elgar, and E.B. Thornton, 1998, Observations and predictions of megaripple migration in a natural surf zone, Nature, 394, 165-168.

Thornton, E.B., J.L. Swayne and J.R. Dingler, 1998, Small-scale morphology related to waves and currents across the surf zone, Marine Geology, 145 (3-4), 173-196.

Faria, A.F.G., E.B. Thornton, T.P. Stanton, C.M.C.V. Soares, and T. Lippmann 1998, Vertical profiles of longshore currents and related bed shear stress bottom roughness, J. Geophys. Res., 103(C2), 3217-3232.

Lippmann, T. and E.B. Thornton, 1999, The Spatial Distribution of Wave Rollers and Turbulent Kinetic Energy on a Barred Beach, (resubmitted to the J. Geophys. Res.)

Lippmann, T.C., C.F. Jorgensen and E.B. Thornton, 1998, Wave slopes and breaking distributions in the surf zone, (resubmitted to the J. Geophys. Res.)

Faria, A.F.G., E.B. Thornton, T.C. Lippmann and T.P. Stanton, 1998, Undertow over a barred beach, (accepted in J. Geophys. Res.)

Faria, A.F.G., E.B. Thornton, T.P. Stanton, T.C. Lippmann 1998, R.T. Guza, and S. Elgar, 1999, A quisi-3D model for longshore currents, (submitted to J. Geophys. Res.)

Huck, M.P., E.B. Thornton and T.P. Stanton, Vertical and horizontal length scales of suspended sediments in the nearshore, submitted to J. Geophysical Research.

Stanton, T.P. and K.M. Kohanowich, Calibration and Application of an Acoustic Doppler Sediment Flux Meter, (submitted to J. Coastal Engineering).

NON-REFEREED PUBLICATIONS

Thornton, E.B. (Editor), 1998, Proc. Coastal Dynamics '97, American Soc. Civil Eng., 1070 pp.

Huck, M.P., E.B. Thornton and T.P. Stanton, 1999, Vertical and horizontal length scales of suspended sediments, Proc. Coastal Sediments '99, Amer. Soc. Civil Eng., 225-240.

Stanton, T.P. and E.B. Thornton, 1999, Sediment Fluxes above a Mobile Sandy Bed in the Nearshore, Proc. Coastal Sediments '99, Amer. Soc. Civil Eng., 241-252.

Romanczyk, W., B. Boczar-Karakiewicz, E.B. Thornton and J.L. Bona, 1999, Sand Bars at Duck, North Carolina, U.S.A.: Observations and Model Predictions, , Proc. Coastal Sediments '99, Amer. Soc. Civil Eng., 491-504.

Blondeaux, P., Stanton, T., Thornton, E., Vittori, G., 1999, Modeling cross-shore mass transport under sea waves. I.A.H.R. Symp. On River, Coastal and Estuarine Morphodynamics, Genova, 6-10 september 1999, vol I, 445-454.

Blondeaux, P., Stanton, T., Thornton, E., Vittori, G., 1999, Reynolds stress measurements from wave field data. I.A.H.R. Symp. On River, Coastal and Estuarine Morphodynamics, Genova, 6-10 september 1999, vol II, 11-19.